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Normal sizes of internal jugular veins in children/adolescents aged birth to 18 years at rest and during the Valsalva maneuver

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ABSTRACT

Objectives: We aimed to establish normal ultrasonographic (US) values of internal jugular vein (IJV) sizes in children/adolescents aged birth to 18 years and to determine the correlation of US measurements with age, height, weight and body surface area (BSA) of children in different age groups.
Methods: Two hundred and thirty-six healthy children (0–18 years) were divided into four groups according to their age (0–2, 3–6, 7–12, and 13–18 years). US measurements (transverse, anteroposterior diameter, and cross-sectional area at rest and during the Valsalva maneuver) of bilateral IJVs were taken at the level of cricoid cartilage.
Results: Our study gives information about the reference values in children between birth to 18 years of age. There were significant differences between measurements taken at rest and during the Valsalva maneuver in all age groups. Moderate to strong correlations (clinically significant) between age, height and BSA of the subjects and IJV measurements were detected only in the 0–2 years age group. The strength of the correlations decreased with increasing age. Pearson's correlation revealed that height had the strongest and weight had the weakest correlation with US measurements. 'Height' was an independent variable on the right, and 'age' on the left side, except for rest CSA, when a regression analysis was performed for clinically significant correlations.
Conclusions: Determination of normal reference values for US measurements of the IJV and knowledge of correlation with age, height, weight and BSA might be valuable during interventional procedures and for the diagnosis of phlebectasia in children/adolescents.

1. Introduction

Internal jugular vein is often the preferred route of central vascular access in children especially in the intensive care units, however jugular vein intervention in children and particularly in infants is technically more difficult than adults secondary to smaller target size, variable position and close proximity to carotid artery [1–4]. While IJV cannulation in adults is almost always successful by either landmark or sonographic guidance methods [5–8], in children the reported values for success rates can be as low as 76% [9] and 78% [10] respectively. Maximizing the cross-sectional area by using maneuvers like Valsalva has been shown to be helpful [1,11–13].

Jugular phlebectasia in children presents as a lateral fusiform neck mass which increases in size with crying and the diagnosis is usually confirmed by ultrasonography (US), however sonographic measurement criteria to call an internal jugular vein 'ectatic' has not been reported until recently [14].

The determination of reliable reference values for internal jugular vein (IJV) diameters at rest and during the Valsalva maneuver in children/adolescents of various age groups might be useful for both medical interventions performed via the IJV and diagnosis of pathological conditions such as phlebectasia. Although the literature includes several studies on IJV diameters and cross-sectional area (CSA) in children, these are generally limited to a specific age interval and do not cover the entire childhood and adolescence [1,11,12,15–19]. Most of them lack appropriate grouping of patients according to age, regarding rapid growth intervals like infancy and adolescence. In addition, findings on the correlation between ultrasound (US) measurements, and patient age and physical variables are inconsistent [1,15,16,20].

The present study aimed to establish normal IJV diameter values in children/adolescents aged birth to 18 years, and to examine the correlation between US measurements, and age, height, weight, and body surface area (BSA) in various age groups. IJV dimensions at rest and during the Valsalva maneuver (VM) were

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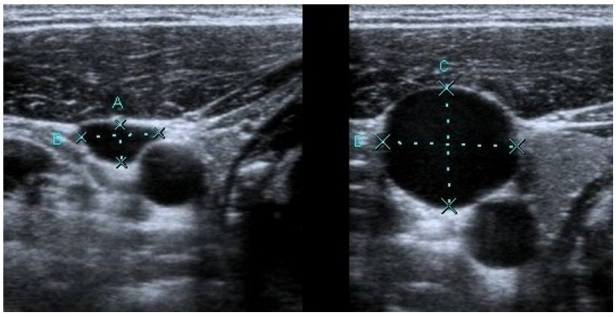

Fig. 1. Sonographic measurement of IJV AP and T diameters at rest (A) and during the VM (B). Calipers indicate the IJV.

measured using US in healthy children with no specific neck complaints.

2. Materials and methods

This prospective study included 236 children/adolescents (124 males and 112 females) aged birth to 18 years (mean age: 88.14 ± 52.3 months) that presented to outpatient clinics at our hospital between April 2010 and April 2012 due to such illnesses as mild upper respiratory tract infection or enuresis nocturna and without a specific neck complaint. Those with anemia, cyanosis, a history of previous jugular line, swelling or trauma, and abnormal neck examination findings at rest or during the VM were excluded. Informed consent was obtained from the parents of the participants and the study protocol was approved by the institutional Ethics Committee.

Weight and height were measured using the same equipment by the same physician (SS). Weight was measured to the nearest 100 g using a digital scale (Seca 767 column scale) and height was measured to the nearest 0.1 cm using a commercial stadiometer (Holtain Harpemden). BSA was calculated using the following weight-based formula [21]:

$$\frac{4W_{kg} + 7}{90 + W_{kg}}.$$

All the participants were imaged via US by the same experienced pediatric radiologist (ASE) using a Logiq 6 ultrasound machine (General Electric Co., Milwaukee, WI, USA) and a 7.5-MHz linear-array small-parts transducer. The participants were placed on the scanning table in the supine position. Their heads were rotated 10–15° to the contralateral side to facilitate contact between the probe and skin. To ensure consistency, all the measurements were obtained at the level of the cricoid cartilage (used as an anatomical landmark). The US probe was applied perpendicular to the skin over a bulk of US gel, without compressing the IJV. Measurements consisted of maximal cross-sectional internal anteroposterior (AP) and transverse (T) diameters, and transverse cross-sectional area (CSA) of the IJV during normal breathing (at rest) and during the VM (Fig. 1 A-B). CSA was measured via planimetry.

Older children were given directions to do the VM. Crying is known to consist of a series of 4 movements that primarily resemble the VM [22]; as such, crying was accepted as the VM equivalent in younger children who could not perform the VM. In all, 37 children aged 0–4 years were evaluated while crying. Babies that did not spontaneously cry during a VM-equivalent measurement were not included in the study. In order to obtain reliable at rest measurements in crying little children, they were either soothed beforehand or the sonographer waited until they were asleep. When necessary, babies were restrained by a physician or parents for stabilization during US scanning. Measurements were repeated 3–5 times, until the physician was satisfied with the success of the VM measurement. The largest measurement was used for analysis in cases of repeated measurements. The participants were divided into 4 age groups, as follows: 0–2 years (0–24 months [infants]); 3–6 years (25–72 months [toddlers]); 7–12 years (73–144 months [children]); 13–18 years (145–216 months [adolescents]).

Statistical analysis was performed using the Statistical Package for Social Sciences v.16.0 for Windows (SPSS Inc., Chicago, IL, USA). Descriptive statistics were shown as frequency, percentage, mean ± SD, and median–interquartile range. The Kolmogorov–Smirnov test was used to evaluate the normality of continuous variables before applying parametric methods. The independent samples *t* test and paired *t* test were used to compare continuous variables, and the Chi-square test was used to compare categorical variables. Analysis of covariance (ANCOVA) for age and sex adjustment was applied.

Pearson's correlation analysis was used to determine the linear association between US measurements, and age, height, weight, and BSA in each age group. The significance of correlations was classified according to Pearson's coefficient (r), as follows: $r = 0.01–0.19$: very weak-negligible correlation; $r = 0.20–0.39$: weak correlation; $r = 0.40–0.69$: moderate correlation; $r = 0.70–0.89$: strong correlation; $r = 0.90–1.00$: very strong correlation. The level of statistical significance was set at $P < 0.05$.

A Pearson's coefficient >0.40 (moderate–strong correlation) and $P < 0.05$ were accepted as a clinically significant correlation. As age, height, weight, and BSA were strongly associated with each other, we performed multiple linear regression analysis to determine which of the variables were independent predictors of the various US measurements with a clinically significant correlation by assuming that each of these variables was a covariate and performing the necessary post-analysis adjustments.

3. Results

Table 1 summarizes the demographic features of the study group, according to age groups. There were no significant differences in weight, height, or age between the males and females ($P > 0.05$).

Table 2 shows the US IJV measurements at rest and during the VM. As no statistically significant difference was identified between males and females in IJV measurements ($P > 0.05$) the data here is presented regardless of sex. There were no significant differences in AP and T diameters, or CSA at rest or during the VM between left-side and right-side measurement in those aged >6 years. At rest T and AP diameters, and T diameter and CSA during the VM in those aged 3–6 years, and CSA during the VM in those aged birth to 2 years differed significantly according to side of measurement; right side values were higher ($P < 0.05$). Comparison of the mean AP, T diameters and CSAs of the left and right IJVs at rest and during the VM showed that there were significant differences between at rest and VM values in all age groups ($P < 0.001$).

Moderate to strong correlations ($r > 0.4$, $P < 0.05$) were noted between age, height, and BSA, and all IJV measurements only in the birth- to 2-year-old age group, except for right-side at rest AP diameter, which had a weak correlation with age and height, and right-side at rest CSA, which had a weak correlation with age. A few moderate correlations were also observed between weight and some IJV diameters in the same age group (0–2 years). The strongest correlations were observed between right-side IJV T diameter and CSA during the VM, and height.

No strong or moderate correlation could be detected between IJV measurements, and age, height, or weight of the subjects in any other age group. In the 3–6 and 7–12-year-old age groups some weak correlations with age, height, and weight could be noted